 0030-0950/82/0001-0014 $2.00/0

POST-PLEISTOCENE DEVELOPMENT OF ROOT-SHAPED FERRUGINOUS CONCRETIONS[1]

RONALD D. STIEGLITZ[2] and ROBERT G. VAN HORN, Ohio Department of Natural Resources, Division of Geological Survey, Columbus, OH 43224

ABSTRACT. During investigations of the surficial geology of Summit County, Ohio, concretions were noted at several locations in the bed and banks of the East Fork Rocky River. The concretions are generally root-shaped, noncalcareous, and concentrically banded by iron hydroxide, with a prominent central tube. They are found in the uppermost portion of Pleistocene lake sediments below coarse sand and gravel. Because the concretions are restricted in occurrence to a few specific localities, their formation results from a unique combination of stratigraphy, materials of the deposit, ground water conditions and the penetration of the silt by plant roots. The concretions are presently forming in the fine-grained silts where roots promote the oxidation of iron compounds by withdrawing water, facilitating the entry of oxygen, and altering surrounding pH conditions.

OHIO J. SCI 82(1): 14, 1982

INTRODUCTION

An investigation of glacial deposits in Summit County, Ohio (fig. 1), revealed the presence of concretions in Pleistocene lacustrine sediments. The concretions are exposed in the bed and banks of East Fork Rocky River in northwestern Summit County. This portion of the county is covered by the West Richfield Quadrangle and is characterized by infilled preglacial valleys containing up to 100 m of stratified glacial materials, and by interstream areas of more resistant bedrock mantled with generally thin Wisconsinan till. The area was affected by ice that pushed southward out of the Lake Erie basin. During retreat, water was at times impounded between the ice to the north and glacial deposits blocking the valleys to the south.

Concretions of similar shape have been reported from a number of localities. Todd (1903) described root-shaped concretions in his general discussion and classification, and Bates (1938) investigated the occurrence of limonite concretions in glacial deposits in Iowa. Smith (1948) reported ferruginous concretions from South Carolina and concluded that roots were not important in their formation. Prokopovich and Bateman (1975) discussed calcareous

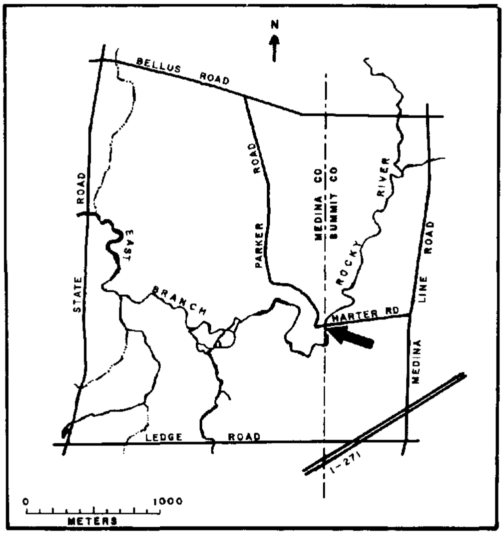

FIGURE 1. Map showing location of study area in western Summit County, Ohio.

[1]Manuscript received 16 August 1976 and in revised form 23 November 1981 (#76–69).

[2]Present address: College of Environmental Sciences, University of Wisconsin-Green Bay, Green Bay, WI 54302.

concretions in the Corcoran Clay of California and decided that they formed during the Pleistocene. Ettensoh (1969) described several types of concretions from Pleistocene lake deposits in Ohio, and cited the importance of ground-water access routes in their formation. One of the best treatments of root-shaped concretions is by Kindle (1923). He presented some excellent photographs, and he clearly recognized central root channels. He concluded that the concretions were Pleistocene in age and formed after the death and decomposition of the root that occupied the central channel. Recently, Theakstone (1981) described concretions occurring in Pleistocene sediments in Norway and concluded that they were still actively forming.

STUDY SITES AND METHODS

The stratigraphic section that exhibits the most prominent concretionary development is diagrammed in figure 2. It is located along the river bank about 15 m south of the Harter Road bridge near the Summit-Medina County line. The lower part of this section consists of 1.2–1.5 meters of gray (2.5Y 5/0) quartz silt (4 in fig. 2), with some fine mica. The silt is oxidized in the uppermost 0.15–0.75 meter (3 in fig. 2). Variations in the thickness of the oxidized horizon probably result from scouring during deposition of the overlying coarser material. Although the contact between the oxidized and unoxidized portions of the silt is undulatory, it is very sharp, and is obvious because of abrupt color change. The silt is noncalcareous and uncemented, and on field examination appears to be homogeneous, without bedding or structures other than the concretions.

Overlying the silt is about 1.0 m of sand- and cobble-size gravel, which in turn is overlain by 0.3 m of imbricated and moderately well sorted cobble gravel (2 in fig. 2). Undifferentiated till units (1 in fig. 2) cap the section. Approximately 10 m to the west of the exposure, these materials abut the flank of a bedrock ridge. Within the oxidized portion of the silt, and extending about 0.3 m downward into the unoxidized material are numerous concretionary structures, generally cylindrical in shape. As observed in the river bank outcrop, they range in diameter from 1–5 cm, and terminate smoothly downward in a cigar-shaped form as much as 25 cm in length. Because of difficulties in excavating these structures, their maximum length is unknown. Many of the concretions have small downward branching protuberances, resembling a dentritic root-growth system. A representative assortment of concretions is shown in figure 3A.

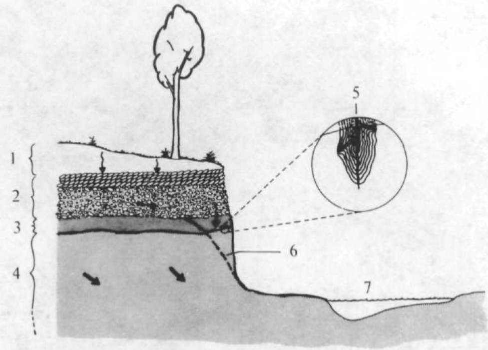

FIGURE 2. Generalized diagram of the stratigraphic and ground water conditions in area of concretionary development. (1) Undifferentiated till; (2) Sand and gravel, imbricated cobble gravel at top; (3) Brown oxidized silt; (4) Gray unoxidized silt; (5) Enlargement of root induced concretion crossing the oxidized-unoxidized contact in the silt; (6) Generalized position of the water table; (7) Surface of East Fork Rocky River.

Several transverse and longitudinal thin sections were made by impregnating selected concretions with polyester resin. Grain mounts of the concretions, and of the oxidized and unoxidized silt matrix that enclosed them, were also prepared for examination.

RESULTS

The concretions, like the enclosing silt, are composed of quartz silt with some mica, and are oxidized, ranging in color from brownish yellow (10YR 6/6) to yellowish brown (10YR 5/6); they are noncalcareous, and are weakly to moderately cemented by iron oxides. Transverse sections exhibit concentric iron-rich bands and a hollow central tube parallel to the long axis (figure 3B). The central tubes range from less than 1–8 mm in diameter. The walls of the tubes are commonly coated with a black film of organic-appearing material, or have organic fragments adhering to them.

In thin sections the concretions consist predominantly of quartz, with a few percent each of plagioclase, clay and fine-grained mica, and cryptocrystalline iron hydroxide. The quartz is angular to subrounded, the grains averaging approximately 0.01 mm in diameter. The plagioclase is generally in the same size

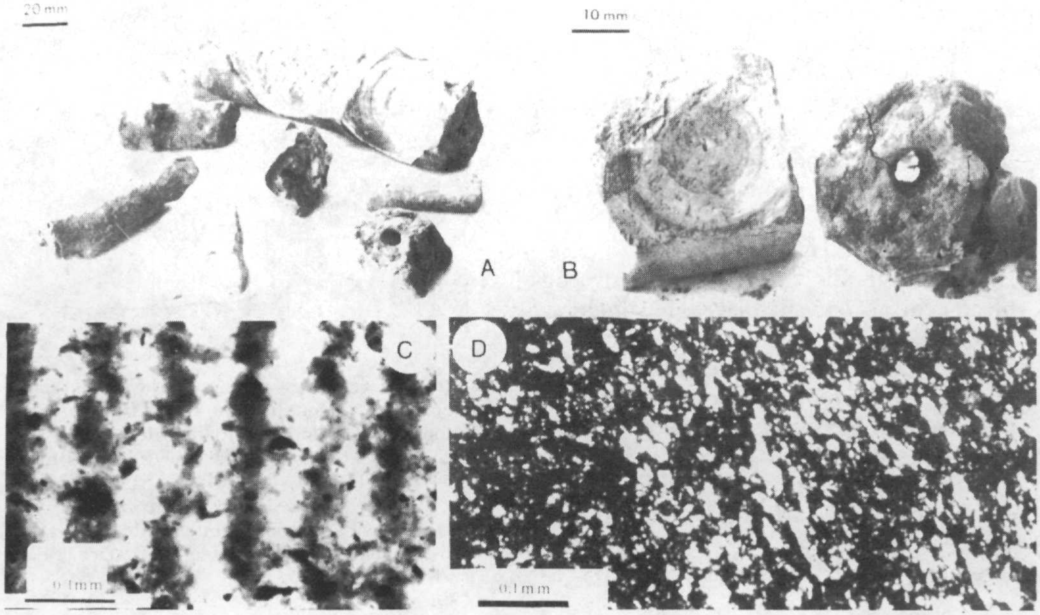

FIGURE 3. (A) Representative assortment of concretions; (B) Transverse section of 2 concretions showing concentric banding and central tube; (C) Photomicrograph of the concentric iron-rich bands of a concretion. Nicols uncrossed; (D) Photomicrograph showing parallel alignment of clay and mica laths. Nicols crossed.

range, but is more angular, and most has undergone some alteration to sericite. The clay and mica are mostly in the form of lathlike crystals, which average about 0.02 mm by 0.003 mm. Iron hydroxide is disseminated throughout the concretions in the form of globules, coatings, and stains, but is primarily concentrated in the concentric rings as shown in figure 3C. In addition to the megascopic rings, microbands of iron hydroxide spaced approximately 0.04 mm apart are visible in thin section.

The mineralogy of the surrounding silt is very similar to that of the concretions. Quartz is the dominant mineral, with small amounts of plagioclase, clay, and fine-grained mica. The most noticeable difference in composition is the greater amount of iron compounds filling the interstices of the oxidized silts and concretions. X-ray diffraction analysis indicated that the major minerals are quartz, goethite, plagioclase, illite, and a small amount of a kaolinite-group mineral.

A preferred alignment of clay and mica laths is evident in micrographs of the silt. There is no general relationship between the orientation of the laths and the concentric iron hydroxide bands or the concretion centers, but at higher magnifications the laths are seen to cross the banding at a high angle and are disrupted by the iron hydroxide bands; these observations suggest that the lath alignment occurred prior to the formation of the concretion. It thus appears to be depositional in nature and has not significantly influenced subsequent concretionary development.

DISCUSSION

The concretions in the silt stratum are apparently restricted to particular localities. None are visible in any of the overlying materials. There are several possible explanations for the areal localization of any iron oxide cemented concretions such as variations in ground-water composition, differences in the permeability or composition of the enclosing material, changes in vegetation, and availability of iron for cement.

Although concretions were observed at only scattered localities, they actually may be more widely distributed. There is, however, a very general correspondence between the nature of the overlying materials and the occurrence of the concretions. In areas of concretionary development, the material overlying the lake silts typically consists of about a meter of coarse imbricated to structureless gravels containing much allochthonous ferruginous material. In areas where the gravels are very thin, or where the overburden is clean alluvial quartz sand, concretions were not found. It is therefore suggested that the overburden may be a primary source of iron compounds found in the concretions and hence a control in the distribution of the concretions.

Surface water percolates downward through the overlying till and gravel. This surface water, having a short flow path, is either not depleted in oxygen or may have its oxygen restored in the porous gravels through atmospheric diffusion. When the oxygenated water reaches the gravel/silt interface, in the vicinity of the stream banks, its flow is deflected laterally, because the silts are essentially saturated, and a hydraulic head is virtually absent. This water continues to move laterally along the gravel/silt interface toward the stream, and eventually flows down the face of the silt outcrop, where surficial oxidation may occur. These conditions are shown schematically in figure 2. The ground water that saturates the silt below the water table possibly is depleted of oxygen by oxidizing materials it encounters along its flow path from relatively more distant recharge points. In the absence of any other localizing mechanism, the silt is sufficiently saturated with oxygen-deficient water to preclude the oxidation of iron compounds.

The function of the central tube is also a factor in the formation and localization of the concretions. Prokopovich and Bateman (1975) and Kindle (1923) suggested that such a feature would provide easy access for the circulation of mineral-bearing water in otherwise impermeable material. The tube may also facilitate the entrance of atmospheric oxygen, with the consequent oxidation and precipitation of iron compounds. We believe that the central tube is not the controlling factor in the formation of the concretions but rather of prime importance is the uptake of water and the metabolic processes of the root that once occupied the tube.

There appears to be a relationship between the roots and the formation of the concretions. We found a living root 2 mm in diameter occupying the central tube of an incipient concretion. An attempt to trace this root to the surface was unsuccessful and hence the parent plant could not be identified. Several concretions were later found containing living roots, while others contained dead, but not decomposed, root remnants. The specimen on the left in figure 3B contains such filament. While vacant tubes may effectively increase permeability, the silts are sufficiently permeable to allow the circulation of mineral-bearing water even in the absence of tubes.

The effects of root growth and water uptake may be fourfold. First, they induce movement of capillary water towards the root. Second, they may allow the penetration of atmospheric oxygen through the gravels and into the silts enclosing the root. Third, they allow penetration of oxygenated surface water as dewatering and root growth continues. Finally, roots absorb nutrients from their surroundings, and also expel certain metabolic byproducts, including carbon dioxide which will alter the pH in the surrounding silt. This may result in physical and chemical conditions that are conducive to the precipitation of iron hydroxide in the vicinity of a root system. Osborn (1960) documented the intake of significant quantities of iron by plants.

The banding of the concretions is not easily explained. It is postulated that, as the uptake of fluids by a root continues, an equilibrium zone is attained. Under equilibrium (or near-equilibrium) conditions, capillary water, which is depleted in free oxygen and contains iron compounds moves toward the root; upon reaching the interface of the zone of water affected by root growth, the iron in solution is oxidized and precipitated as goethite. If uniform conditions are maintained, the precipitation of iron hydroxide at this interface may be sufficient to produce a visible ring; a short-term equilibrium would produce one of the observed microbands. Perhaps once initiated the precipitation of the iron hydroxide acts to provide a site for further precipitation and to establish surrounding zones of similar chemical conditions. Although an individual band of iron hyroxide may represent an annual or seasonal deposit, we do not suggest that the number of rings equals the number of years of concretion growth. Rather, it is likely that a ring represents an occurrence of a specialized combination of weather, ground water, and plant growth. It is possible that the effects of the roots are only important at these unusual times to trigger concretion development. Several rings could be precipitated in one year, or a single ring may represent stabilized conditions over a number of years.

There may be other variables, such as the presence of specific plant types or the distance behind an outcrop face, which control the formation and distributon of these concretions. It appears that they form as iron compounds are oxidized and precipitated in response to a complex and fluctuating geochemical environment. It is not our intent to analyze the geochemistry in the vicinity of the developing concretions in detail. No doubt it is multifaceted because of geological materials, water sources, flow patterns, and the presence of living plants and decaying organic matter. Hem (1960) and Hem and Cropper (1959) long ago called attention to the complexities of iron solubility. Not only are solubilities involved but also acid-base chemistry and oxidation-reduction reactions.

The concretions are presently forming and a Holocene age is indicated for the majority of those observed. We found no evidence, such as truncation, deformation, or infilling, that suggests formation during glacial times. A sequence of concretions, ranging from poorly cemented forms to examples that are well indurated, also support ongoing formation. We do feel that a mechanism is necessary to initiate and localize iron hydroxide precipitation and to explain the formation, shape, and distribution of the concretions. Simple ground water fluctuations are not adequate to explain the observed features. The effects of the root actions may be such a mechanism.

ACKNOWLEDGMENTS. This paper is published with the permission of the Chief, Division of Geological Survey, Ohio D. N. R. The authors thank Dr. Richard W. Carlton and Mr. David A. Stith of the Ohio Division of Geologial Survey for help with the x-ray analyses. Dr. Carlton and Jean Simmons Brown, Survey Editor, read the manuscript. Drs. Michael Morgan and James Wiersma of the College of Environmental Sciences, University of Wisconsin-Green Bay, offered valuable suggestions pertaining to plant root functions and chemistry of iron.

LITERATURE CITED

Bates, R. L. 1938 Occurrence and origin of certain limonite concretions. J. Sed. Petrol. 8: 91–99.

Ettensoh, R. R. 1969 The influence of ground water access routes on concretionary development in preglacial lake sediments. Geol. Soc. Amer. Abs. with Programs, pt. 7, p. 59–60.

Hem, J. D. 1960 Restraints on dissolved ferrous iron imposed by bicarbonate redox potential and pH. U. S. Geol. Survey Water-Supply Paper 1459-B. p. 32–55.

——— and W. H. Cropper 1959 Survey of ferrous-ferric chemical equilibria and redox potentials: U. S. Geol. Survey Water-Supply Paper 1459-A. 31 p.

Kindle, E. M. 1923 Range and distribution of certain types of Canadian Pleistocene concretions. Bull. Geol. Soc. Amer. 34: 609–648.

Osborn, E. T. 1960 A survey of pertinent biochemical literature. U. S. Geol. Survey Water-Supply Paper 1459-F. p. 111–190.

Prokopovich, N. P. and R. L. Bateman 1975 Calcareous concretions in the Corcoran Clay, western Merced County, California. California Geol. 28: 75–81.

Smith, L. L. 1948 Hollow ferruginous concretions in South Carolina. J. Geol. 56: 218–225.

Theakstone, W. H. 1981 Concretions in glacial sediments at Seglvatnet, Norway. J. Sed. Petrol. 51: 191–196.

Todd, J. E. 1903 Concretions and their geological effects. Bull. Geol. Soc. Amer. 14: 353–368.